Industrial Technologies Program

Crosscutting Industrial Applications of a New Class of Ultrahard Borides

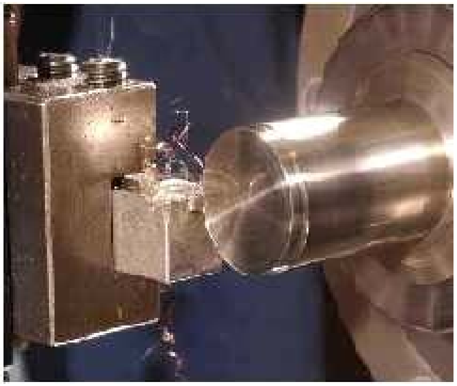
New $AlMgB_{14}$ Composites Offer Significant Improvements in Wear Resistance

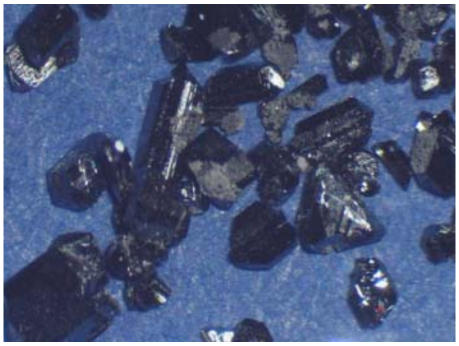
Estimates of the cost to the U.S. economy of wear and degradation of materials amount to over $100 billion annually. Wear of materials not only limits industrial productivity and economic progress; the effects of wear also result in a considerable waste of energy across a broad span of industrial operations. Recent studies indicate that nanoscale $AlMgB_{14}$ composites exhibit an unprecedented resistance to wear, suggesting a new paradigm for degradation-resistant materials. In tests against a wide range of current-generation hard and ultra-hard materials, these boride composites show superior abrasive and erosive wear resistance under severe conditions. The development of improved, wear-resistant materials and coatings is expected to benefit a wide range of industries, ranging from petrochemical to mining and metalcasting.

Research into improved wear-resistant materials is also an enabling technology, fostering subsequent development of new processes and products across all industries.

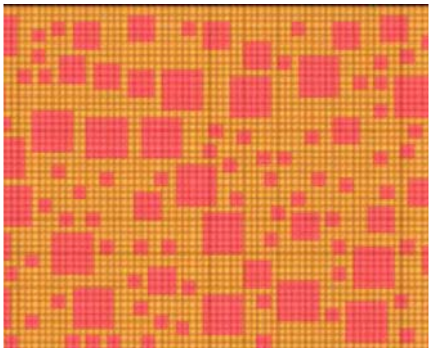
High-speed machining tests on gray cast iron

Lathe cutting tests on 304 steel





"BAM" grit



Micro-structural model

Benefits for Our Industry and Our Nation

- *A 30% market in abrasive pump wear components is projected to result in total energy savings of 5 TBtu per year.*
- *A 10% market in the current U.S. metalcasting industry (grinding and finishing) could save an additional 5 TBtu of energy per year.*
- *A 10% improvement in performance in the mining industry's drilling, coring, boring, and grinding equipment would result in direct savings of $100 million per year. A more efficient grinding tool that enables a 25% increase in speed could lower energy demands by 100 billion Btu.*
- *A 2.5% reduction in electric power consumed for cutting operations industry-wide may result in a reduction of CO_2 emissions in the United States by 2 x 10^6 metric tons.*

Applications in Our Nation's Industry

Because of the wide range of possible applications for ultrahard borides, this project describes a broad-based effort to develop and transfer this technology to four key industries:

- Agriculture
- Metalcasting
- Forest Products
- Mining

Project Description

The goal of this project is to develop a new class of highly wear-resistant bulk and thin film composite materials to serve the metalcasting, mining, forest products, petrochemical, and agriculture industries.

Barriers

- Abrasive slurry pumps are typically operated at a maximum of 1/3 to 1/2 of their rated speed in order to mitigate wear; differential pumping pressures in abrasive applications are limited to roughly 60% of non-abrasive levels, limiting throughput and decreasing energy efficiency of the pumps
- Maximum machining speed for Ti and Ti alloys is constrained by the available tooling materials as a consequence of accelerated diffusional wear. Adhesive wear between tool and workpiece decreases energy efficiency of metal removing processes.
- Implementation of efficient high-pressure abrasive jet technology is limited by abrasive wear of the nozzle assembly

Pathways

The objectives of this project will be achieved through (1) study of advanced mixing and blending technologies to achieve the desired distribution of reinforcement without concomitant introduction of deleterious contaminants; (2) development of a high-strength, high toughness binder phase possessing compatible surface energy and thermal expansion; (3) examination of thin film deposition technologies and properties of hardfacing boride coatings on various substrate materials; (4) collaboration with established powder processing and consolidation organizations to establish cost-effective large-scale processing routes; (5) development of suitable microstructure-property models to guide processing optimization; (6) interaction with industrial partners on evaluation of laboratory-scale materials and implementation of feedback in refinement and optimization of processing; and (7) providing ongoing technical support for commercialization efforts.

Milestones

Results To Date

- Developed a novel Co-Mn binder phase alloy for boride tooling inserts
- Achieved a hardness and toughness combination of 32 GPa and 10 MPa sqrt(m) in the baseline $AlMgB_{14}$ cermet
- Obtained a microhardness of 48 GPa in $AlMgB_{14}$-TiB_2 composite
- Achieved a factor of 42 improvement over standard-grade cemented carbide during a mass loss erosive wear test
- Achieved lower abrasive wear rates than either cemented carbide or cubic BN
- Developed high-hardness $AlMgB_{14}$ thin film coatings with a friction coefficient of 0.04

Future Milestones

- Expand thin film deposition research to encompass wear-resistant composite compositions
- Examine magnetron sputtering as a potential pilot-plant-scale deposition technology
- Identify range of composition and reinforcement leading to optimum abrasive and erosive wear resistance
- Identify optimum reinforcement phase and distribution
- Develop cost-effective processing technology to produce desired microstructures in industrial-scale quantities
- Develop industry-wide consensus on improved wear resistance of boride composites
- Provide technical support for emerging commercialization efforts

Commercialization

Commercialization of technologies developed at Iowa State University is administered through the Iowa State University Research Foundation, which holds patent rights to all ISU ultrahard boride compositions. Recent improvements in wear resistance of these materials have increased awareness of their potential to provide substantial improvements in productivity and energy efficiency across a wide range of industrial applications. Licensing strategies and options are currently being negotiated between ISURF and interested parties.

Project Partners

Ames Laboratory, Iowa State University
Ames, IA
(Dr. Bruce A. Cook: cook@ameslab.gov)

The University of Arkansas
Fayetteville, AR

Praxair Surface Technologies
Indianapolis, IN

Kennametal Advanced Solns. Group
Latrobe, PA

Michigan Technical University
Houghton, MI

The University of Missouri
High-Pressure Water Jet Laboratory
Rolla, MO

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

U.S. Department of Energy
Energy Efficiency and Renewable Energy

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